

REMARKS

Claims 1-9, 11-14, 16-19 and 21-30 are pending in this application.

Claims 1-9, 16-19, 21-24, 29 and 30 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Huang et al. (U.S. Patent No. 6,313,028), in view of Applicants' Admitted Prior Art ("APA"), Lopatin (U.S. Patent No. 6,368,954), Krishnan et al. (U.S. Patent No. 5,451,551) and Jang (U.S. Patent No. 6,110,648), a total of *five* different references. This rejection is respectfully traversed.

The claimed invention relates to a method of forming a copper damascene structure. As such, independent claim 1 recites a "method of forming a copper damascene structure" by *inter alia* "providing a metal layer within a semiconductor substrate," "forming a low-dielectric constant layer over and in contact with said metal layer" and "directly patterning said low-dielectric constant layer to form at least one opening through said low-dielectric constant layer, said opening extending to at least a portion of said metal layer." Independent claim 1 also recites "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions" and "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing." Independent claim 1 further recites "subsequently providing a copper layer in said at least one opening and in contact with said tungsten nitride layer, wherein said copper layer is selectively deposited by low-temperature metal-organic chemical vapor deposition."

Independent claim 17 recites a method of forming a copper damascene structure by *inter alia* "forming a material layer of methylsilsequiazane over a substrate," "forming at least one opening through said methylsilsequiazane layer by etching said methylsilsequiazane layer with a tetra-methyl-ammonium hydroxide

solution” and “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening.” Independent claim 17 also recites “removing horizontal portions of said tungsten nitride layer formed above and in contact with a top surface of said methylsilsequiazane layer” and “subsequently providing a copper layer in said at least one opening.”

The subject matter of claims 1-9, 16-19, 21-24, 29 and 30 would not have been obvious over Huang in view of the APA, Lopatin, Krishnan and Jang. Specifically, the Office Action fails to establish a *prima facie* case of obviousness. Courts have generally recognized that a showing of a *prima facie* case of obviousness necessitates three requirements: (i) some suggestion or motivation, either in the references themselves or in the knowledge of a person of ordinary skill in the art, to modify the reference or combine the reference teachings; (ii) a reasonable expectation of success; and (iii) the prior art references must teach or suggest all claim limitations. See e.g., In re Dembiczak, 175 F.3d 994 (Fed. Cir. 1999); In re Rouffet, 149 F.3d 1350, 1355 (Fed. Cir. 1998); Pro-Mold & Tool Co. v. Great Lakes Plastics, Inc., 75 F.3d 1568, 1573 (Fed. Cir. 1996).

Huang relates to a method of fabricating a dual damascene. Huang teaches that “[a] dielectric layer is formed on a substrate” and “[a] diffusion barrier layer is formed on the dielectric layer,” so that “[a] portion of the diffusion barrier layer and the dielectric layer is removed to form a trench and a via hole.” (Abstract). Huang also teaches that “[a] barrier layer is formed on the diffusion barrier layer and in the trench and the via hole.” (Abstract). Once the barrier layer on the diffusion barrier layer is removed by chemical-mechanical polishing, “[a] conductive layer is formed in the trench and the via hole by selective deposition.” (Abstract).

In the present case, neither Huang nor the numerous secondary references relied on by the Office Action, whether considered alone or in combination, disclose, teach or suggest all limitations of independent claims 1 and 17. Huang does not disclose, teach or suggest *“providing a metal layer within a semiconductor substrate,” “forming a low-dielectric constant layer over and in contact with said metal layer”* and *“directly patterning said low-dielectric constant layer to form at least one opening through said low-dielectric constant layer, said opening extending to at least a portion of said metal layer,”* as independent claim 1 recites. Huang teaches the formation of conductive layer 202, which the Office Action appears to argue corresponds to the “metal layer” of the claimed invention, within the substrate 200. (Col. 3, lines 4-6). Huang also teaches the formation of the dielectric layer 206, which the Office Action appears to argue corresponds to the “low-dielectric constant layer” of the claimed invention, over the substrate 200. (Col. 3, lines 6-8). However, in Huang, dielectric layer 206 is not formed “over and in contact with” the conductive layer 202. Rather, in Huang, a cap layer 204 is formed *between* the conductive layer 202 and the dielectric layer 206.

Huang is also silent about “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions” or about “subsequently providing a copper layer in said at least one opening and in contact with said tungsten nitride layer, wherein said copper layer is selectively deposited by low-temperature metal-organic chemical vapor deposition,” as independent claim 1 recites. Huang teaches that conformal barrier layer 212, which might arguably correspond to the “tungsten nitride layer” of the claimed invention, could be formed of tungsten nitride material. However, Huang does not disclose, teach or suggest “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions,” as in the claimed invention.

In addition, Huang is silent about “providing a copper layer in said at least one opening and in contact with said tungsten nitride layer,” as independent claim 1 recites. Huang specifically emphasizes that “[i]n a case where a material of the conductive layer 214 is copper, the material of the barrier layer 212 is preferably Ta/TaN.” (Col. 4, lines 5-7). This is because, as Huang explains, “[d]uring the selective chemical vapor deposition of the copper conductive layer 214, the Ta/TaN barrier layer 212 serves as an activation center for selective chemical vapor deposition.” (Col. 4, lines 11-14). Thus, Huang teaches that, when copper is selected as the material for the conductive layer 214, a Ta/TaN barrier layer is employed and not a “tungsten nitride layer,” much less a “tungsten nitride layer by atomic-layer deposition using sequential surface reactions,” as in the claimed invention.

Huang also fails to disclose, teach or suggest all limitations of independent claim 17. Huang is silent about “forming a material layer of methylsilsequiazane over a substrate,” much less about “forming at least one opening through said methylsilsequiazane layer by etching said methylsilsequiazane layer with a tetramethyl-ammonium hydroxide solution,” as in the claimed invention. Huang teaches that dielectric layer 206 “is preferably a silicon oxide layer formed by plasma-enhanced chemical vapor deposition (PECVD), or spin-on polymer (SOP) with a low dielectric constant” (col. 3, lines 23-26), and not a “methylsilsequiazane layer,” as in the claimed invention.

As noted above, Huang also fails to teach or suggest “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions” or “removing horizontal portions of said tungsten nitride layer formed above and in contact with a top surface of said methylsilsequiazane layer,” as independent claim 17 recites. In Huang, diffusion barrier layer 207 is formed over the dielectric layer 206. Thus, subsequent to the trench and via formation, barrier layer 212 of Huang is formed

over and in contact with the diffusion barrier layer 207, and not “above and in contact with a top surface of said methylsilsequiazane layer,” as in the claimed invention.

The APA also fails to teach or suggest all limitations of independent claims 1 and 17. The APA does not teach or suggest a “method of forming a copper damascene structure” by *inter alia* “directly patterning said low-dielectric constant layer to form at least one opening,” “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions” and “removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing,” as independent claim 1 recites.

Lopatin likewise fails to teach or suggest all limitations of independent claims 1 and 17. Lopatin does not teach or suggest a “method of forming a copper damascene structure” by *inter alia* “directly patterning said low-dielectric constant layer to form at least one opening,” “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions” and “removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing,” as independent claim 1 recites. Lopatin also fails to disclose, teach or suggest all limitations of independent claim 17.

Krishnan also does not teach or suggest all limitations of independent claims 1 and 17. The Office Action states at page 2 of the office action that “Krishnan et al discloses selective CVD of Cu in an opening in an ILD by removal of a barrier layer 24 by CMP followed by formation of the Cu layer 32 by selective CVD (fig 21-25). The barrier layer 24 is disclosed to be TiW and the ILD 16 is disclosed to be oxide.” However, nowhere does Krishnan disclose a “method of forming a copper damascene structure” by *inter alia* “directly patterning said low-dielectric constant layer to form at least one opening,” “forming a tungsten nitride layer by atomic-layer deposition using

sequential surface reactions” and “removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing,” as independent claim 1 recites. Krishnan also fails to disclose, teach or suggest, alone or in combination with the above references, all limitations of independent claim 17.

Finally, Jang also does not teach or suggest all limitations of independent claims 1 and 17. The Office Action states at page 2 of the office action that “Jang discloses formation of WN 160 within a via opening but not on the surface of the ILD 120a/120b followed by CMP of the copper to remove the Cu from the surface of the ILD. The *preferability of etching* as opposed to CMP is related to formation of the recessed Cu layer.” (Emphasis added.) Nowhere does Jang disclose a “method of forming a copper damascene structure” by, *inter alia*, “directly patterning said low-dielectric constant layer to form at least one opening,” “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions” and “removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing,” as independent claim 1 recites. Jang also fails to disclose, teach or suggest, alone or in combination with the numerous references above, all limitations of independent claim 17.

Applicants reiterate that the combination of Huang with any or all of the cited secondary references fails to disclose, teach or suggest all limitations of independent claims 1 and 17. For example, neither Huang, nor any or all of the four secondary references, whether considered alone or in combination, discloses, teaches or suggests “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions” and “removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing” (Claim 1) or “forming a tungsten nitride layer by atomic-layer deposition

using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening” and “removing horizontal portions of said tungsten nitride layer formed above and in contact with a top surface of said methylsilsequiazane layer” (Claim 17).

In addition, the Office Action provides no suggestion to combine any of the references cited beyond a multi-step assertion on page 2 of the office action that “it would have been within the scope of one of ordinary skill in the art *to omit formation layer 207* of Huang et al in the process of the combination of Huang et al, the APA and Lopatin in view of the teachings of Krishnan et al related to polishing of a barrier layer formed directly on an ILD layer followed by selective CVD of Cu and those of Jang related to formation of the structure of fig 23 of Krishnan et al using the recited materials.” (emphasis added.) Even assuming that all the limitations of the claimed invention may be extracted from Huang and the four secondary references, there is no *motivation* to combine these references in a way that would correspond to the invention described in claims 1 or 17.

The rejection relies on improper hindsight in combining the references. Using Applicants’ claimed invention as a roadmap, the Office Action improperly pulls together a multitude of prior art references and declares that “[i]t would have been within the scope of one of ordinary skill” to have combined these references in a manner described nowhere except in Applicants’ claims. Whether a combination is within the *scope* of one of ordinary skill is not the proper inquiry; the test is whether it would have been *obvious* to one of ordinary skill in the art to have combined these references in such a way. Without Applicants’ claims 1 and 17 as a guide, there is no motivation to combine these references in a way that would arrive at Applicants’ claimed invention.

A person of ordinary skill in the art would not have been motivated to combine these references; they would not have produced the claimed invention and they address different problems and provide different advantages. Indeed, in at least two instances, the Office Action arbitrarily removes or modifies a feature of a reference in an attempt to match the roadmap provided by Applicants' claims. First, the office action asserts at page 2 that "[i]t would have been within the scope of one of ordinary skill in the art to omit formation of layer 207 of Huang et al." The office action provides no motivation for purposefully omitting this step. Indeed, the omission of the formation of layer 207 in Huang would destroy a key teaching of the reference. Huang teaches at Col. 3, lines 26-28, "[t]he diffusion barrier layer 207 is used to prevent the conductive layer 202 from diffusing into the dielectric layer 206 while depositing the conductive layer 202." It would make no technical sense for one having ordinary skill in the art to remove a key feature of Huang without motivation.

Further, in shoehorning the CMP limitation of Jang into Huang (already heavily modified by the office action's arbitrary removal of layer 207, as well as by three other references), the office action admits on page 2 that Jang indicates a preference for etching as opposed to CMP. Indeed, Jang states at Col. 6, lines 54-56 that "controlled removal of copper from a cavity or recess is very difficult if chemical mechanical polishing (CMP) is used. The office action attempts to explain away this second discrepancy by asserting that "[t]he preferability of etching as opposed to CMP is related to formation of the recessed Cu layer." However, this does not address the fact that Jang does not contain any suggestion to combine CMP with the modified Huang reference. Rather than support the argument that it would have been obvious to combine these references, this statement in the office action merely underscores the divergent scope and teachings of the references; it supports the proposition that one of

ordinary skill in the art would not have found it obvious to combine these references in a way that would arrive at Applicants' claimed invention.

For at least these reasons, the Office Action fails to establish a *prima facie* case of obviousness. Withdrawal of the rejection of claims 1-9, 16-19, 21-24, 29 and 30 is respectfully requested.

Claims 14 and 28 are rejected under 35 U.S.C. §103(a) as being unpatentable over Huang in view of the APA, Lopatin and Shachan-Diamand et al. This rejection is respectfully traversed.

As noted, the claimed invention relates to a method of forming a copper damascene structure. As such, independent claim 14 recites a "method of forming a copper damascene structure" by *inter alia* "directly patterning a low-dielectric constant layer with a mask to form at least one opening through said low-dielectric constant layer," "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening, said tungsten nitride layer being formed above and in contact with a top surface of said low-dielectric constant layer" and "removing horizontal portions of said tungsten nitride layer formed above and in contact with said top surface of said low-dielectric constant layer by chemical mechanical polishing." Independent claim 14 also recites "subsequently providing a copper layer in said at least one opening, wherein said copper layer is formed by contact displacement copper deposition at room temperature."

None of Huang, the APA, Lopatin or Shachan-Diamand, whether considered alone or in combination, discloses, teaches or suggests all limitations of independent

claim 14. Huang does not disclose, teach or suggest “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions.” As noted above, although Huang mentions tungsten nitride as one of the materials for the formation of barrier layer 212, Huang is silent about “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions.”

Huang also fails to teach or suggest that the tungsten nitride layer is “being formed above and in contact with a top surface of said low-dielectric constant layer,” as independent claim 14 recites. In Huang, diffusion barrier layer 207 is formed over the dielectric layer 206. (Col. 3, lines 6-8). Thus, subsequent to the trench and via formation, barrier layer 212 of Huang is formed over and in contact with the diffusion barrier layer 207, and not “above and in contact with a top surface of said low-dielectric constant layer,” as in the claimed invention. Applicants also submit that the APA and Shachan-Diamand do not disclose, teach or suggest all limitations of independent claim 14.

Further, the combination of Huang, the APA, Lopatin and Shachan-Diamand does not disclose, teach or suggest all limitations of the claimed invention. For example, none of Huang, the APA, Lopatin or Shachan-Diamand, whether considered alone or in combination, discloses, teaches or suggests “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening, said tungsten nitride layer being formed above and in contact with a top surface of said low-dielectric constant layer” and “removing horizontal portions of said tungsten nitride layer formed above and in contact with said top surface of said low-dielectric constant layer by chemical mechanical polishing,” as independent claim 14 recites.

Claim 28 is dependent on claim 17, the rejection of which has been discussed above. In view of that rejection and of the above discussion of similar limitations in independent claim 14, Applicants submit that none of Huang, the APA, Lopatin or Shachan-Diamond teach or suggest all the limitations of the claimed invention. Applicants also submit that if the Office Action were to include Krishnan and Jang in the rejection analysis, as in the rejection of independent claim 17 (on which claim 28 depends), the references would still not teach or suggest all the limitations of the claimed invention.

Accordingly, the Office Action fails again to establish a *prima facie* case of obviousness. Withdrawal of the rejection of claims 14 and 28 is also respectfully requested.

Claims 11-13 and 25-27 are rejected under 35 U.S.C. §103(a) as being unpatentable over Huang in view of the APA and Lopatin and further in view of Kaloyeros. This rejection is respectfully traversed.

As noted above, Huang, the APA and Lopatin, whether considered alone or in combination, fail to teach each and every limitation of independent claims 1 and 17. Kaloyeros, alone or in combination with Huang, the APA and Lopatin, (and with or without Krishnan and Jang) also fails to disclose, teach or suggest all limitations of these claims. Applicants submit that if the Office Action were to include Krishnan and Jang in the rejection analysis, as in the rejection of independent claims 1 (on which claims 11-13 depend) and 17 (on which claims 25-27 depend), the references would still not teach or suggest all the limitations of the claimed invention. For at least these reasons, Applicants submit that claims 11-13 and 25-27 are allowable.

In view of the above, each of the presently pending claims in this application is believed to be in immediate condition for allowance. Accordingly, the Examiner is respectfully requested to pass this application to issue.

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Respectfully submitted,

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